United Nations A/AC.105/770

General Assembly

Distr.: General
30 November 2001

Original: English

Committee on the Peaceful Uses of Outer Space

National research on space debris, safety of space objects with nuclear power sources on board and problems relating to their collision with space debris

Note by the Secretariat

Contents

		Paragraphs	Page
I.	Introduction	1-2	2
II.	Replies received from Member States		2
	Australia		2
	Finland		3
	Iran (Islamic Republic of)		3
	Republic of Korea		4
	United Kingdom of Great Britain and Northern Ireland		4
	United States of America		7
III.	Replies received from international organizations		9
	A. United Nations		9
	International Telecommunication Union		9
	B. Other international organizations		9
	International Astronomical Union		9

V.01-89171 (E) 040102 070102

I. Introduction

1. At its forty-fourth session, the Committee on the Peaceful Uses of Outer Space agreed that Member States should continue to be invited to report to the Secretary-General annually with regard to national and international research concerning the safety of space objects with nuclear power sources, that further studies should be conducted on the issue of collision between space debris and orbiting space objects with nuclear power sources on board and that the Committee's Scientific and Technical Subcommittee should be kept informed of the results of such studies.[1] The Committee also took note of the agreement of the Subcommittee that national research on space debris should continue and that Member States and international organizations should make available to all interested parties the results of that research, including information on practices adopted that had proved effective in minimizing the creation of space debris (A/AC.105/761, para. 127).

2. In a note verbale dated 8 August 2001, the Secretary-General requested Governments to submit any information on the above questions by 31 October 2001 so that it could be submitted to the Scientific and Technical Subcommittee at its thirty-ninth session. The present note has been prepared by the Secretariat on the basis of information received from Member States by 3 December 2001. Information received subsequent to that date will be included in addenda to the present document.

II. Replies received from Member States

Australia

1. Australia's report discusses debris mitigation procedures in the context of the operation of domestic space launch facilities. While there are no space launch facilities currently operational, there are several firm proposals to establish such facilities in the near future. Australia's report also discusses activities undertaken by the private sector with regard to debris management.

Licensing arrangements

2. Australia does not manufacture satellites at the present stage, with the exception of the small experimental FedSat 1 satellite. However, as a potential launching country, Australia is concerned about the impact of nuclear-driven activities in space.

3. Under Australia's space licensing regime, applicants must satisfy strict safety and environmental requirements. In addition, space objects cannot contain nuclear weapons or fissionable materials unless the approval of the Minister has been gained. Under these three sets of legal requirements, the regime is strict about nuclear sources in space debris.

Asia Pacific Space Centre

4. The Asia Pacific Space Centre is establishing a commercial space launch facility on Christmas Island. The Centre will use the Russian Aurora launch vehicle, which will consist of three stages plus an upper optional stage, and will target geostationary launches. It is planned to commence launches in 2004.

5. The Government of Australia has completed a full assessment of the impact of the proposed launch facility on the environment and made a number of recommendations to the company. Among the issues addressed by those recommendations were the potential for orbital debris generation in both normal operation and malfunction conditions, the potential for orbital debris generation due to on-orbit impact with existing space debris or other orbiting space systems and the potential for items to pose a safety or environmental threat upon re-entry.

6. The Centre has developed an Environmental Management Plan, which sets out strategies to address those recommendations. In line with the *ESA Space Debris Mitigation Handbook* published by the European Space Agency (ESA) in 1999, the plan advises that no objects be released by either the stage 3 separation or the kick-stage (Corvet) separation. This means that no small debris is to be generated and, hence, that there is no contribution to space debris from mission-related objects.

[1] *Official Records of the General Assembly, Fifty-sixth Session, Supplement No. 20* and corrigendum (A/56/20 and Corr.1), para. 108.

7. Passivation is used in stage 3 and Corvet, which removes the danger of a later explosion. This will result in one object being tracked rather than the potential for numerous objects resulting from an uncontrolled explosion. When the Corvet is used and the mission permits, stage 3 can be de-orbited using sub-orbital separation. The kick stage (Corvet) is also capable of active de-orbiting when the mission permits.

Other space launch proposals

8. The remaining proposals to establish space launch facilities have not advanced to a point where they are in a position to provide advice about debris mitigation procedures.

Electro-optic systems

9. Research specific to debris avoidance is undertaken by Electro Optic Systems, an Australian company specializing in electro-optic space tracking systems. Over the past several years, Electro Optic Systems has developed a new generation of laser and optical tracking devices for tracking and cataloguing space debris. The research and development of the new technologies was supported directly by the Government of Australia through funding and facility-sharing.

10. In full-scale trials, the new tracking systems have demonstrated the ability to accurately track debris of 1 centimetre (cm) in size up to altitudes of 800 kilometres. The technology includes the ability to acquire previously unknown debris objects of that size, in large numbers, and the potential catalogue will expand from 20,000 objects to 100,000 objects using the technology. The present global infrastructure can track debris down to 10 cm in size and has a capacity of about 15,000 debris objects. Deployment of tracking infrastructure to allow expansion and maintenance of the debris catalogue by Electro Optic Systems is now under way in several countries. The company plans to make the new debris catalogue available on a commercial basis from 2003.

Australian commitment

11. Australia is concerned about the risks posed by space debris, in particular about geostationary orbit (GEO) satellites, and is aware that there have been a number of near collisions in recent years. The loss of bandwidth for lengthy periods in the event of such a collision is one consequence with far-reaching implications for the global industry.

12. Australia endorses the need to ensure that space continues to be accessible and safe. To that end, Australia remains committed to supporting measures to minimize the harmful effects of debris in space, through avoidance, regulatory and mitigation measures. Integrated coordinated tracking and technologies to facilitate de- and re-orbiting of potentially dangerous satellites and debris have an important role to play in that regard.

Finland

Finland has several ongoing space debris research activities and applications:

(a) DEBIE space debris sensors and data-processing units were launched on board the PROBA satellite in October 2001;

(b) DEBIE will later fly on the International Space Station in a more operational role;

(c) A low-Earth orbit (LEO) space debris survey was carried out using European incoherent scatter (EISCAT) radars (demonstrated capability: 1-cm and larger objects) in Lapland;

(d) The University of Oulu Sodankylä Geophysics Observatory carried out a contract study for the ESA European Space Operations Centre to measure small-sized space debris;

(e) The University of Turku carried out a geostationary orbit space debris survey using the European Space Agency's telescope in the Canary Islands.

Iran (Islamic Republic of)

Owing to the effects of humankind's aerospace activities on the environmental health of the Earth, space debris has emerged in recent decades as a problem seriously threatening the survival of orbiting spacecraft, space platforms and astronauts carrying out space walks in near-Earth orbit. Space debris research in the Islamic Republic of Iran is carried out through the orbital debris team of the Aerospace Research Institute as a part of the Space Standards and Law Research Group. The orbital debris team is working on

a variety of subjects, such as categorization, characteristics, tracking and laws relating to orbital debris. Mathematical simulation, collision probability functions and hazard analysis are prospective topics for the Group's studies.

Republic of Korea

1. On the issue of the safety of space objects with nuclear power sources, the Republic of Korea has never used nuclear power sources and does not plan to use them in the near future. Therefore, the Republic of Korea has fully implemented the safety of space objects without nuclear power sources.

2. On the issue of space debris, the Republic of Korea does not yet have its own space launch vehicle. Therefore, the issue does not yet concern space activities in the Republic of Korea. However, a Republic of Korea launcher will be launched in 2005. In that case, the Republic of Korea will do its best to minimize the creation of space debris.

United Kingdom of Great Britain and Northern Ireland

I. Introduction

1. The continued commitment of the British National Space Centre (BNSC) to addressing the space debris issue is outlined in its *UK Space Strategy Report (1999-2002)*. A key objective is to coordinate with other agencies that are also working on the threat posed by space debris. In that regard, BNSC co-ordinates national activities through the United Kingdom Space Debris Coordination Group and ensures that those activities are harmonized with those of ESA and its member States via the ESA Coordinating Group on Space Debris. Through its membership of the Inter-Agency Space Debris Coordination Committee (IADC), BNSC is actively pursuing international agreement on a variety of space debris issues. It also supports the related programme of work in the Committee on the Peaceful Uses of Outer Space.

2. National meetings provide a forum for the co-ordination of all debris research activities in the United Kingdom. The group enables researchers to exchange information and ideas and, where possible, fosters collaborative opportunities. The group last met in November 2001, and most of the major debris research groups in industry and academia in the United Kingdom participated. These included QinetiQ (formerly DERA), the Ministry of Defence, Astrium, Century Dynamics, Observatory Sciences, Advanced System Architectures, the Rutherford Appleton Laboratory, the Open University and the Universities of Cranfield, Oxford and Southampton.

3. ESA coordination of space debris is now managed by a network of centres for space debris involving the Italian Space Agency (ASI), BNSC, the Centre national d'études spatiales of France and the German Aerospace Centre (DLR), with participation open to all ESA members active in the area of space debris.

4. IADC is an international forum for cooperation on all aspects of the debris problem. In particular, efforts within the group are focused on achieving agreement on recommended mitigation practices based on sound technical analysis of the problem. Within the last year, the United Kingdom participated in the 19th IADC meeting, which was hosted by DLR in March 2001. The 20th IADC meeting will be hosted by BNSC at the University of Surrey in April 2002.

5. The United Kingdom has particularly strong debris research capabilities, which BNSC regularly calls upon for impartial technical support and advice. During the past year, organizations in the United Kingdom have conducted the research and development activities outlined below.

II. Observation and measurement of the debris population

A. Debris camera system

6. Sira Electro-Optics Ltd has been involved in the supply of an electronic debris camera system in collaboration with Carl Zeiss Jena for ESA. This has been installed on a 1-metre (m) diameter Zeiss telescope at the Teide Observatory in Tenerife. Extensive test observations with the telescope and Sira's camera were carried out from December 2000 until July 2001. The optical observations were focused on GEO and its vicinity, the so-called geostationary ring. This is one of the most heavily used regions in space, with about 300 operational spacecraft. Unfortunately, break-ups of a rocket upper stage and a

satellite are known to have occurred, but the locations of the fragments were largely unknown, since routine activities of the US Space Surveillance Network ignore objects in GEO smaller than about 1 m in size. With the Zeiss 1-m telescope a large number of debris objects were detected and their orbits determined in a preliminary manner. The limiting magnitude is slightly beyond 20 for 2 seconds' exposure time, which corresponds to a minimum object size of 10-20 cm. The test observations have thus led to the discovery and partial characterization of a large population of small-size debris objects in GEO. Currently the charge-coupled device (CCD) camera, including dewar, are at Carl Zeiss Jena for final work. It is expected that the final test observations on Tenerife will be resumed by November 2001.

B. Debris radar

7. A collaborative arrangement between the Rutherford Appleton Laboratory and QinetiQ has been established to develop the 3-gigahertz (GHz) radar system at the Chilbolton Observatory in Hampshire for space debris detection. Although this uses a fully steerable 25-m antenna, the existing magnetron transmitter, used principally for radar meteorology, has insufficient power to detect all but the largest debris objects. During the past year, a travelling wave tube transmitter has been installed and this will provide a much higher mean power capability (2.7 kilowatt (kW) as opposed to 600 W). The new system will be fully coherent and allow the detection of objects as small as 5 cm in diameter up to a range of 1,000 km (i.e. in the LEO region). Testing of the new system is expected to be completed in early 2002.

III. Debris environment modelling

8. Modelling of the debris environment, its long-term evolution and the potential risks it causes to possible future space systems continues to be a major activity amongst debris researchers in the United Kingdom. The effect of continually introducing new assets into near-Earth space and therefore the consequences for the debris environment is also a key research area.

A. Modelling the debris environment in low-Earth orbits

9. During the past year, QinetiQ has focused on the study of space debris mitigation measures in terms of their long-term benefits in reducing future debris growth, the costs involved in implementing those measures and the risk implications to important space assets. The study has been achieved by significant improvements to the long-term space debris environment models, IDES (for the Ministry of Defence of the United Kingdom) and DELTA (for ESA) and the development of a stand-alone tool called DEORBITER for post-mission manoeuvre planning and propellant estimation. A special presentation on cost-effectiveness of space debris mitigation measures was made at the meeting in Vienna in February 2001 of the Committee on the Peaceful Uses of Outer Space. An extensive analysis of long-term debris environment evolution, debris mitigation measures and spacecraft protection has been performed for the *Update of the ESA Space Debris Mitigation Handbook*. Technical leadership and input has been provided to a key international study on LEO end-of-life disposal for the development of IADC space debris mitigation guidelines.

10. In 2001 the University of Southampton began a new work project concerned with space "tethers". A space tether is a long, high-strength cable, which is generally used to connect spacecraft to each other. The tether provides a mechanical connection that enables the transfer of energy and momentum from one object to another and as a result can be used as a form of space propulsion. It can also interact with the Earth's magnetosphere to generate power or propulsion. Tethers are increasingly being considered for use in Earth orbit. The work at Southampton focuses on tether dynamics, the vulnerability of tethers in the space debris environment and the converse effect that tethers have on the environment.

B. Modelling the debris environment in high-Earth orbits

11. The IDES and DELTA models (developed by QinetiQ) have both been extended to predict the long-term evolution of the orbital debris environment in low-Earth orbit, medium-Earth orbit and geosynchronous Earth orbit regions simultaneously. Similarly, the long-term prediction of collision risk in any Earth

orbit (including highly eccentric orbits) is also possible, based upon full population dynamics simulation.

12. The main thrust of research at the University of Southampton during the period has been in the area of GEO debris. A software analysis tool is being developed, under a contract sponsored by the United Kingdom Engineering and Physical Sciences Research Council ("The long-term evolution of space debris in high-Earth orbit"). The software, called Debris Analysis and Monitoring Architecture for the Geosynchronous Environment (DAMAGE), will include novel features and techniques to assess the long-term evolution of the high-Earth orbit debris environment and the risk to orbiting systems in that region. The model now incorporates a reference population of objects intersecting the geosynchronous environment, two control volumes and an orbital propagator featuring perturbations arising from the major zonal spherical harmonics, low-order tesseral harmonics, luni-solar gravitation and solar radiation pressure. Much effort has been expended in developing and validating the propagator in close collaboration with QinetiQ. The model's development is now continuing with the addition of several collision risk assessment algorithms and an explosion model. The applications of the tool include investigation of the stability of the environment and of end-of-life spacecraft disposal strategies.

13. During the past year, an international consortium comprising the University of Kent, QinetiQ, Onera (Toulouse, France), the Max Planck Institute (Heidelberg, Germany) and the University of Maryland (United States of America) has completed an ESA contract to extend modelling of space debris and other environmental factors from LEO to GEO. In particular, quantitative assessments of the interactions and modelling of population dynamics have been undertaken. As part of that activity, a model for predicting GEO populations has been developed and tested (DIADEM). This is linked to Master 99 (the comprehensive ESA tool for characterizing the debris and meteoroid flux environment).

IV. Spacecraft debris protection and risk assessment

14. The assessment of risk to and protection of spacecraft from hypervelocity debris impacts is another research area in which the United Kingdom is very active.

A. Satellite survivability modelling

15. QinetiQ has completed development of version 1.0 of an innovative and unique software model called SHIELD, whose purpose is to evaluate the survivability of unmanned spacecraft designs in the debris environment and to recommend appropriate cost-effective debris protection strategies. An initial set of validation simulations has recently been performed and demonstrated that a high degree of confidence can be placed in the results from SHIELD. An invited paper illustrating some of the capabilities and results from the model was presented at the International Astronautical Federation Congress in Brazil in 2000.

B. Hypervelocity impact simulation

16. Century Dynamics continues to sell and provide support for the AUTODYN hydrocode software to the worldwide space community. The model is used to simulate the response of a material under hypervelocity impact. The company has numerous customers directly involved in space debris studies relating to hypervelocity impact protection. ESA, the European Aeronautic Defence and Space Company, the National Aeronautics and Space Administration (NASA) of the United States and the National Space Development Agency of Japan and many of their contractors continue to use AUTODYN. There is a wider usage of AUTODYN for non-metallic materials such as glass and composites. Within the last year, Century Dynamics has launched the AutoShield software, which is specifically designed for the numerical analysis of hypervelocity impact shielding studies.

17. The company continues to be involved in contract work for ESA/Alenia relating to the validation of the International Space Station's Columbus shielding design. It has also participated in several other contracts related to hypervelocity impacts on satellite structures and components.

C. Engineering spacecraft for debris risk reduction

18. The Earth Observation and Science Directorate of Astrium Ltd continues to work in the field of debris engineering, looking at spacecraft systems engineering and mission analysis. NASA tools and ESA research, as well as in-house tools, are used for analysis of

satellite collision risk and end-of-life de-orbit. Research continues into unmanned spacecraft shields and associated structures. During the past year, this has included the development of a filament-wound carbon fibre structure, which is combined with Kevlar shielding layers.

United States of America

1. Space debris research and operations in the United States of America remained very active in 2001 and important advances in both measurements and modelling were achieved. The Space Shuttle and the International Space Station continued their space debris countermeasure procedures and reported no significant damage. NASA was a major participant in the Third European Conference on Space Debris in Darmstadt, Germany, in March 2001, with 19 technical papers. Six additional papers were presented by NASA at the 52nd International Astronautical Congress in Toulouse, France, in October.

2. Two United States long-duration spacecraft were retired in 2001 and placed in disposal orbits to mitigate risks to other satellites. The 24-year-old GOES 2 satellite was moved to a storage orbit above the geosynchronous regime (35,785 km +/- 200 km). The 19-year-old Landsat 4 satellite was taken out of its Sun-synchronous orbit near 700 km and manoeuvred into a lower orbit to ensure that it did not remain in LEO for more than 25 years after completion of the mission.

3. The United States Government continued its activities to ensure a full understanding of United States policies and practices with regard to debris mitigation, both internally and with industry. For example, representatives from each of the NASA centres and various contractors attended a colloquium on orbital debris at NASA headquarters in April. The prime objective of the meeting was to review NASA policy and guidelines for the mitigation of space debris in Earth orbit. A special NASA-wide meeting on risks associated with re-entering satellites was held at the NASA Johnson Space Center in June. Also, in April, the annual meeting of the NASA/Department of Defense Orbital Debris Working Group was held in Colorado Springs, Colorado.

4. The United States provided tracking information to the Russian Federation in support of the highly successful operations to de-orbit the Mir space station in March and participated in the Mir re-entry workshop at the European Space Operations Centre in May. In addition, the United States was pleased to participate in the March and October meetings of IADC.

Space debris impact hazards and shielding research

5. The potential hazards of space debris, specifically meteoroids, was an important issue during the first decade of the space age, when little was known about the space environment. Simple spacecraft designs were found to offer adequate protection against this natural threat for relatively short missions. Today's longer-duration spacecraft face the challenges of not only the natural particle environment but also an increasing one of man's own creation.

6. Since the return and examination of components of the Solar Maximum Mission satellite by the Space Shuttle in 1984, the United States has renewed its investigations of space debris impact hazards and shielding. That same Space Shuttle mission also deployed NASA's Long-Duration Exposure Facility (LDEF), which provided extensive space debris impact data upon its retrieval six years later. More than 30,000 LDEF impact sites—an average impact rate of 15 per day or nearly one per revolution about the Earth—were identified. Similar impact features are routinely observed on the Hubble Space Telescope and the Space Shuttle itself.

7. Particles of up to 1 millimetre (mm) in diameter do not normally cause significant damage to spacecraft systems. However, spacecraft engineers must compensate for the long-term effects of such high-speed impacts in their designs, especially for power-generation and thermal control systems. Prolonged exposure to space debris particles can reduce power output as a result of the loss of individual solar cells or their connections and can lead to lower efficiencies of heat rejection surfaces.

8. Following 12 Space Shuttle missions during the period from October 1998 to April 2001, a total of 30 outer window panes were replaced because of small meteoroid and orbital debris impacts. This represents a nearly 25 per cent replacement rate per flight for the 11 principal windows on the Space Shuttle. As indicated in this Subcommittee's *Technical Report on*

Space Debris,[2] the origins of particles of this size are now almost equally divided between natural and man-made sources.

9. Owing to the hypervelocity of most space debris impacts, even very small particles can achieve high relative kinetic energies that can lead to damage features much larger than the particles themselves. For example, a 0.1-mm aluminium impactor caused a 2-mm crater in a Space Shuttle window during a flight in the year 2000. In 1998, a 0.3-mm paint particle created a 1-mm diameter hole in a Space Shuttle radiator. During the past few years, the Space Shuttle radiators have been modified to reduce the probability of penetration and the potential subsequent breach of a thermal control system coolant tube.

10. In 2001, space debris holes were found on the International Space Station, one discovered during a space walk and others during the inspection of the Leonardo multi-purpose logistics module after its inaugural flight of less than two weeks. One of the more serious impacts by space debris of less than 1 mm in diameter was caused by a 0.4-mm particle that penetrated a cloth covering and struck a Space Shuttle manifold line. The force of the impact resulted in a crater with a depth of half the line thickness and causing part of the wall on the coolant side to detach. A slightly larger or faster-moving particle might have caused a coolant leak, prematurely terminating the mission.

11. Occasionally, particles larger than 1 mm will also strike spacecraft, although the flux of 1-mm particles at the International Space Station altitudes is 1,000 times less than that of 0.1-mm particles. On several flights, the Space Shuttle has been struck by space debris 1-2 mm in diameter. Two pieces of stainless steel debris of this size struck the Space Shuttle Columbia in 1996 and a 2-mm piece of aluminium hit the Space Shuttle Atlantis in 1997. Fortunately, those impacts occurred on relatively rugged, non-critical surfaces.

12. The largest known impact on a United States spacecraft was found on one of the high-gain antennas of the Hubble Space Telescope during the first servicing mission in 1993. A hole with a diameter of 1.9 cm was discovered by the crew of the Space Shuttle Endeavour. A particle large enough to cause that level of damage could have resulted in a serious malfunction for many satellites, including those used for human space flight.

13. To determine the vulnerability of specific spacecraft components and structures, hypervelocity impact tests in terrestrial laboratories have proved very valuable. Using conventional two-stage, light-gas guns, projectile velocities of up to 7 kilometres per second (km/s) can be obtained. Velocities as high as 11 km/s are possible with inhibited shaped-charges. Such facilities enable researchers to evaluate the effects of particle size, composition, shape, impact velocity and impact angle. Major hypervelocity impact testing facilities are located in the United States at the NASA White Sands Test Facility and the Air Force Arnold Engineering Development Center.

14. To reduce testing requirements and to predict the effects of impacts at velocities higher than 11 km/s, physics-based computer simulations, called hydrocodes, are employed. Together, the test and hydrocode results permit the development of ballistic limit equations, in other words, mathematical relationships that indicate under what conditions a surface will be penetrated by debris. Penetration is the principal measure of merit in evaluating protection capabilities.

15. Overall space vehicle risk assessments are determined by combining the space debris environment model with a detailed description of the space vehicle, including its numerous ballistic limit equations for each type of surface. The NASA bumper model is used for such evaluations for the Space Shuttle, the International Space Station and robotic satellites, by calculating the probabilities of impact and penetration over a specified time interval.

16. Debris shields may be necessary to meet spacecraft requirements for the probability of no penetration. Vehicles are inherently shielded to some degree against small space debris by the spacecraft structure and insulation materials. The simplest type of shielding is called a Whipple shield and consists of a thin (typically aluminium) sheet of material called a bumper, which is attached a short distance in front of the surface to be protected. When a space debris particle strikes the bumper, a pressure shock propagates through the particle and the bumper, creating a debris cloud of smaller, less hazardous fragments. By the time the debris cloud reaches the spacecraft surface, the fragments are spread over a

[2] United Nations publication, Sales No. E.99.I.17.

larger area, reducing the energy per unit area imparted to the spacecraft structure.

17. The stuffed Whipple shield, pioneered by NASA and also known as a multi-shock shield, employs the basic Whipple shield design but incorporates additional, light-weight material between the bumper and the spacecraft surface. Typical materials placed behind the bumper are Kevlar and Nextel. By varying the bumper material, thickness and stand-off distance, as well as the number and type of intermediate layers, stuffed Whipple shields can be efficiently tailored to protect a given spacecraft surface from a defined space debris threat with a total shield mass significantly less than a simple Whipple shield.

18. On the International Space Station, more than 300 types of Whipple and stuffed Whipple shields will be used to guard against particles as large as 1-2 cm in diameter. For example, one stuffed Whipple shield for the Destiny Laboratory Module is 10.7 cm in depth and consists of a 0.2-cm aluminium bumper, multi-layer insulation, six layers of Nextel and six layers of Kevlar in front of the 0.48 cm-thick module wall. This shield can prevent penetration of a 1.35-cm aluminium particle impacting head-on at a velocity of 7 km/s.

19. A mesh double bumper debris shield is a variation of the stuffed Whipple shield with a thin metal mesh placed in front of the solid bumper. The mesh helps disrupt the debris particle before reaching the second, conventional bumper.

20. NASA has also developed a new debris shield design that is particularly attractive for large, inflatable space vehicles. A sample configuration uses a "sandwich" of four layers of Nextel (two sheets each) and one layer of Kevlar, all separated by low-density foam. During launch, the shield can be stowed in a small volume and then extended on-orbit to a height of 75 cm to provide the necessary separation between the Nextel and Kevlar sheets to make the shield effective. Such a configuration can stop aluminium particles of up to 1.8 cm in diameter travelling at 7 km/s.

III. Replies received from international organizations

A. United Nations

International Telecommunication Union

There is no information relevant to this topic arising from the work of technical study groups within the Radiocommunication Sector of the International Telecommunication Union.

B. Other international organizations

International Astronomical Union

The International Astronomical Union regards the space debris problem as an important item among the environmental issues affecting the science of astronomy—in particular but not exclusively the part carried out from satellites. The International Astronomical Union will follow the work on practical debris mitigation measures initiated by the Committee on the Peaceful Uses of Outer Space as a follow-up to the recommendations of the Third United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE III) with great interest and expects to make some contributions to that work. Otherwise, given the nature of the International Astronomical Union, members of the Union contribute to the subject as part of their professional activity in national and international space agencies, but the Union does not conduct an independent programme in the area.

United Nations A/AC.105/771

General Assembly

Distr.: General
6 December 2001

Original: English

Committee on the Peaceful Uses of Outer Space

United Nations/United States of America Workshop on the Use of Global Navigation Satellite Systems

(Kuala Lumpur, 20-24 August 2001)

Contents

		Paragraphs	Page
I.	Introduction	1-9	3
	A. Background and objectives	1-6	3
	B. Programme	7	3
	C. Attendance	8-9	4
II.	Observations and recommendations	10-21	4
	A. Existing and future GNSS systems and their applications	12	4
	B. Overview of the current and expected GNSS applications market	13-14	4
	C. GNSS for land management	15	5
	D. National programmes in the region	16	5
	E. Disaster preparedness and environmental monitoring	17	6
	F. Conservation of resources	18	6
	G. Precision agriculture	19	6
	H. Surveying and mapping	20	6
	I. GPS for timing and transportation	21	7

V.01-89454 (E) 080102 090102

III.	Summary of country reports	22-36	7
	A. Bangladesh	22-27	7
	B. Cambodia	28	8
	C. Maldives	29	8
	D. Pakistan	30-31	8
	E. Sri Lanka	32	8
	F. Tonga	33	9
	G. Turkey	34-35	9
	H. Uzbekistan	36	9

I. Introduction

A. Background and objectives

1. The Third United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE III) and the Vienna Declaration on Space and Human Development recommended that activities of the United Nations Programme on Space Applications promote collaborative participation among Member States at both the regional and international levels, emphasizing the development of knowledge and skills in developing countries.[1]

2. The Global Navigation Satellite System (GNSS) is one of the most promising space applications that can be used to achieve the recommendations made by UNISPACE III. The need has been identified to determine precise locations on the ground for use with Earth observation images and ancillary information in geographical information systems (GIS). Such location information is needed for a large number of remote sensing applications, some of which support such strategic areas for development as disaster management, monitoring and protecting the environment, management of natural resources and food production. With the availability of high-resolution images, certain applications will require a location precision of the order of one metre. The GNSS, which includes the Global Positioning System (GPS) of the United States of America, provides a signal that can serve that purpose and can also be used for a large range of other applications with economic benefits for the user.

3. The present report concerns the regional workshop, held in Kuala Lumpur from 20 to 24 August 2001, the first in a series being co-sponsored by the United Nations Programme on Space Applications and the Government of the United States of America. The workshop was organized in cooperation with the Government of Malaysia for the benefit of developing countries of the region of Asia and the Pacific. It was hosted by the Department of Survey and Mapping Malaysia, Ministry of Land and Cooperative Development.

4. The workshop focused on specific applications of the use of existing GNSS and their augmentations to further global environment objectives and enhance sustainable development programmes and to deepen the understanding of those applications in developing countries. Such global systems include the GPS of the United States and the Global Navigation Satellite System (GLONASS) of the Russian Federation. Applications include monitoring of the environment, precision agriculture, surveying and mapping, resource conservation, disaster management, transportation and timing and others.

5. The objectives of the workshop were (a) to bring the benefits of the availability and use of GNSS signals to the awareness of decision makers and technical personnel from potential user institutions as well as to service providers in the private sector, in particular in developing countries; and (b) to identify actions that could be taken and partnerships to be established by potential users. The workshop was also intended to increase the awareness of participants of the intrinsic value of GNSS signals in a sustainable development context and to motivate them to make use of GNSS in their own work. A direct result would be an expanded user base, which would be likely to include a network of experienced and beginner users from governmental and academic institutions as well as from the private sector.

6. In order to reach those objectives, the applications of the GNSS were reviewed, with special emphasis on (a) the current status and modernization policy of GPS (United States); the current status and future development of GLONASS (Russian Federation); (b) existing and future potential applications of those systems for sustainable development and protection of the environment of interest for countries in the region; and (c) promotion of regional and international cooperation.

B. Programme

7. At the opening of the workshop keynote addresses were given by the Director of the Office for Outer Space Affairs and Kasitan Gaddam, Minister of Land and Cooperative Development of Malaysia. The programme was divided into eight sessions: (a) existing and future GNSS systems and their applications; (b) GNSS for land management; (c) national programmes in the region; (d) disaster preparedness and environmental monitoring;

(e) conservation of resources; (f) precision agriculture; (g) surveying and mapping; and (h) GPS for timing and transportation. Country reports from countries of the region were also delivered. The workshop ended with a session on observations and recommendations.

C. Attendance

8. Participants at the workshop came from the following countries: Australia, Austria, Bangladesh, Brunei Darussalam, Cambodia, China, India, Indonesia, Japan, Lao People's Democratic Republic, Malaysia, Maldives, Pakistan, Republic of Korea, Russian Federation, Singapore, Sri Lanka, Tonga, Turkey, Tuvalu, Viet Nam, United Kingdom of Great Britain and Northern Ireland, United States and Uzbekistan. The International Maritime Organization (IMO) and the Office for Outer Space Affairs were also represented.

9. Funds allocated by the United Nations and the United States were used to defray the costs of air travel and daily subsistence allowance of 27 participants from 18 countries and the Office for Outer Space Affairs. The Government of Malaysia, through its Department of Survey and Mapping Malaysia, Ministry of Land and Cooperative Development, provided board for all United Nations-sponsored participants. The programme for the workshop was developed by the Office for Outer Space Affairs and the State Department of the United States in cooperation with the Department of Survey and Mapping Malaysia.

II. Observations and recommendations

10. Electronic versions of all the presentations and country reports submitted, as well as observations/findings (which contains a summary of the presentations) and recommendations, are located on the web site of the Department of Survey and Mapping Malaysia at the following address: http://www.jupem.gov.my/gnss.htm (The full version of the observations and findings of the workshop can be found under the heading "Summary GNSS"; presentations are located under "Paper GNSS"; and country reports appear under "Speech GNSS".)

11. The recommendations of the workshop are summarized below.

A. Existing and future GNSS systems and their applications

12. The workshop recommended:

(a) Implementation of the recommendations of UNISPACE III in order to facilitate usage of GNSS (GPS, GLONASS) technology applications for the development of Asian and Pacific countries;

(b) Reduction of the potential to restrict modernization of GPS;

(c) Maintenance and modernization of GPS/GLONASS as a part of core GNSS;

(d) Establishment of channels of communication among GNSS national points of contact in order to promote future discussion;

(e) Seeking international support to further mutual interests as regards GPS and a modernized and enhanced GLONASS;

(f) Development of regional consensus on the frequency spectrum to ensure implementation to modernize GPS and GLONASS;

(g) Obtaining users' feedback as regards new GPS and GLONASS systems;

(h) Maintenance of a free signal from GNSS on a non-discriminatory basis;

(i) Increase in value added services;

(j) Continuing discussion to achieve a target of interoperable capability between GPS/GLONASS and Galileo.

B. Overview of the current and expected GNSS applications market

13. The workshop recommended:

(a) Evaluation of the impact of selected availability mode turn-off on consumer use;

(b) Renewal of old data recorded when selected availability was turned on;

(c) Taking advantage of the growing user community and of emerging applications;

(d) Obtaining more information about possible cooperation with the National Aeronautics and Space Administration (NASA) of the United States.

14. It also recommended that:

(a) Government and private enterprises work together to determine the boundaries for the provision of differential GPS (DGPS) services. At present there is an effective market where user needs are being met on a commercial basis. New technology is being developed and provided to satisfy user demands on a competitive basis. Developments by private companies are an important source of industry innovation;

(b) Many enhancements be made to real-time kinematic technology, such as:

(i) Ergonomic improvements in equipment;

(ii) On-the-fly initialization;

(iii) Reduction in time-to-initialize and increased initialization reliability;

(iv) Low-latency positioning;

(v) Moving baseline real-time kinematic technology.

C. GNSS for land management

15. The workshop recommended that:

(a) Systematic techniques and procedures be designed to help surveyors in Viet Nam to overcome difficulties in understanding the use of GPS;

(b) In order to extend the use of GNSS in GIS in India, the following be done:

(i) Digitization of existing paper map design;

(ii) Establishment of GPS-based control points;

(iii) Establish precisely located control points;

(iv) Design of a rectangular grid coordinate system;

(v) Transposition of existing triangular stations and boundary pillars to the new coordinate system;

(vi) Use of kinematic GPS to create digital records adopting the new coordinate system;

(c) The GIS community should develop coherent arguments to persuade Governments of the key role of GIS as a basis for electronic government (governing by electronic means).

D. National programmes in the region

16. The workshop recommended that:

(a) The Indian Satellite-Based Augmentation System (SBAS), almost operational by the end of 2005, be:

(i) A seamless navigation system, international in nature and with the same standards as the wide-area augmentation system (WAAS), the European Geostationary Navigation Overlay Service and the Multifunctional Transport Satellite Satellite-Based Augmentation System (MSAS);

(ii) A part of the evolving GNSS;

(iii) An active participant in the interoperability group of which the Federal Aviation Administration, European Tripartite Group and MSAS are members;

(b) SBAS may need European assistance for early trials through the navigational payload on INMARSAT-III for the Indian Ocean region. However, it is planned to put a navigational payload in one or two Indian geostationary communication satellites (of the GSAT/INSAT series) for dedicated use by the civil aviation community;

(c) Governments (by active participation through the establishment of steering committees):

(i) Establish a national plan on GNSS;

(ii) Establish user support groups;

(iii) Set up an augmentation infrastructure for the system;

(iv) Remove tax from GNSS-related products;

(v) Provide long-term protection of the GNSS/radio navigation system spectrum;

(vi) Maintain close contact with other countries in the development of GNSS technology for application in survey, mapping and other fields such as geological survey, marine navigation and boundary demarcation.

E. Disaster preparedness and environmental monitoring

17. The workshop recommended that:

(a) Disasters be minimized or even prevented by connecting all national safety management systems by means of an information network;

(b) An integrated system incorporating the use of GIS and GPS technologies for systematic efforts to cope with disasters efficiently and to minimize the loss of lives be established;

(c) The importance of using GIS and GPS for the implementation of national disaster management systems be recognized;

(d) GPS be used as an effective tool for real-time monitoring of bridge motion;

(e) GPS be used to improve the reliability and safety of transport services;

(f) Applications of GPS and/or the Indonesian INSAR satellite be further studied to monitor landslide mitigation in Indonesia. (Landslides are one of the major geohazards continuously affecting the Indonesian population, especially in the rainy season.);

(g) The methodology of "no net rotation" constraint be used in the construction of the international terrestrial reference frame.

F. Conservation of resources

18. The workshop recommended that:

(a) Scientific research be conducted in several areas, including for the study of height datum unification of sea-level using GPS installed on buoys and sea vessels;

(b) GPS be used for:

(i) Classification of forest cover;

(ii) Assessment of the spatial variability of gaps and gap sizes in forests.

G. Precision agriculture

19. In the area of GNSS applications to precision agriculture, the workshop recommended:

(a) The development of information requirements for the following technologies and techniques:

(i) GPS;

(ii) DGPS;

(iii) Real-time DGPS services;

(iv) DGPS augmentation systems;

(v) Mobile mapping;

(vi) Application software and GIS;

(vii) Hand-held personal computers;

(b) Increased efficiency and reduction of the impact on the environment from agrochemical inputs in agricultural production through site-specific management using GPS, GIS, sensor systems and variable-rate technology;

(c) Improvement in user information technology capability in positioning systems, with emphasis on high accuracy in mapping at low cost;

(d) Provision of more reliable real-time navigation signals and systems for variable-rate application;

(e) Establishment of a worldwide information exchange centre network related to precision agriculture.

H. Surveying and mapping

20. The workshop recommended that:

(a) The same re-observation and re-adjustment be performed for the network of scientific instruments for east Malaysia;

(b) Countries intending to use GNSS in the future be aware of the development of GNSS infrastructure, such as the modernization of GPS and the development of the Galileo and other systems. New

GNSS infrastucture should overcome some of the current limitations, thus giving more accurate results in a shorter time and at lower cost, and covering larger areas.

I. GPS for timing and transportation

21. The workshop recommended that:

(a) A GNSS forum be established by IMO on operational requirements, performance standards and institutional arrangements;

(b) User requirements in DGPS for navigation be reviewed;

(c) Standards and practices related to GNSS be constantly developed to meet the needs of the maritime industry;

(d) Time compatibility between the GPS and Galileo systems be addressed to ensure inter-operability. Studies and simulations needed to be conducted in that regard;

(e) The potential for local contributions to the Aeronautical Navigation Satellite System in Indonesia be taken into account in future activities related to its utilization and development;

(f) The current status of the WAAS and the local area augmentation system (LAAS) initial operational capability for the certified WAAS signal should be taken into account. The signal is expected to be introduced in December 2003. LAAS Category I landing should be operational in 2003.

III. Summary of country reports

A. Bangladesh

22. Application of GPS has already proved to be very effective in certain development activities in Bangladesh. The use of GPS technology effectively started in a number of institutions in the early 1990s. The Bangladesh Space Research and Remote Sensing Organization is using GPS for collecting control points for geo-referencing remotely sensed data. The other regular application of GPS by the Organization is to locate the position of the features in the field for collecting ground truth data. Such data were also used during the devastating floods of 1998 to identify and delineate flood-affected areas, which helped the concerned authorities considerably in taking appropriate and timely measures. The Local Government Engineering Department has produced Upazilla and Pourashava base maps using GPS. The Department has been carrying out an extensive field survey using GPS to develop a road network database that will subsequently be used in planning physical structures. The road network database (mainly for rural areas) has already been completed for more than 50 per cent of the country.

1. Survey of Bangladesh

23. In 1992, under the auspices of the Japan International Cooperation Agency, a geodetic survey was carried out throughout the country by the Survey of Bangladesh. Extensive information was collected for the study using DGPS all over the country.

2. Geological Survey of Bangladesh

24. The Geological Survey of Bangladesh has been a user of GPS since 1995. In 1997-1998, the technology was used for drilling mines in the country. In recent years, it has been used to identify locations of tube wells in arsenic-affected areas throughout the country. A study on coastal dynamics is expected to be undertaken by the Government of Bangladesh in the near future where identification of flood plain elevation will be necessary to assess those dynamics.

3. Bangladesh Water Development Board

25. The Bangladesh Water Development Board uses GPS in flood monitoring, especially in determining location-based flood depth and its extension during flood time.

4. Environment and Geographic Information System

26. The Environment and Geographic Information System uses GPS for location information specifically for identifying water sector features in different parts of the country.

27. In order to improve the usage of GNSS technologies in Bangladesh, three main points may be considered. Firstly, GNSS is not a well known technology in Bangladesh. It is therefore essential to

create awareness of the usefulness of the technology among potential users. Such awareness can be created through the arrangement of workshops/seminars on the applications of GPS/GNSS. Secondly, it is essential to define the potential field(s) of application of GNSS in the Bangladeshi context. This can be done through a detailed survey of the relevant ongoing activities of the Government and non-governmental organizations. Thirdly, in Bangladesh, as an economically developing country, users should be given an opportunity to access the technology at an affordable price. Therefore, the cost of the GNSS receiving systems should be reduced.

B. Cambodia

28. GPS is widely used in Cambodia by various governmental and non-governmental organizations and a number of foreign and local private companies. The Cambodian organizations that are using GPS data are the State Secretariat of Civil Aviation, the Ministry of Metrology, the Ministry of Transportation, the Ministry of Land Management, Urban Planning and Construction, the National Committee for the Mekong River and the National Committee for Border Affairs. Cambodia needs much international support and technical assistance in the field of training and human resources.

C. Maldives

29. The following recommendations are offered for the GPS navigation system:

(a) Increase in the memory of GPS receivers. Each atoll in Maldives has almost 1,000 shallow patches and coral reefs that are very hazardous to navigation, especially at night. Additional memory would thus enable users to store those shallow patches in the GPS equipment memory;

(b) Increased zoom capability of charts;

(c) Improved loading capability. For some GPS receivers it takes a long time to load data, especially during adverse weather conditions;

(d) Large screens are needed to show details of charts used for navigation on GPS receivers;

(e) Access to DGPS transmission frequencies is needed in the region.

D. Pakistan

30. In Pakistan, GNSS technology is being used by the Survey of Pakistan, for its cartographic applications, the City Police Liaison Committee, for tracking and geo-positioning of vehicles in cases of theft and other crimes, and the Hydrography Department, for marine survey and generation of hydrographic charts for navigational purposes.

31. DGPS data are an important component in the balloon soundings programme of the Space and Upper Atmosphere Research Commission for the determination of vertical wind profile and wind weighting factors for carrying out rocket experiments. In the Commission's satellite remote sensing and GIS application activities, this technology is being routinely used to obtain ground control points, geographical coordinates and elevation data for geometric correction and ortho-rectification of remote sensing images. With the availability of high-resolution satellite data of one metre and less than one metre, the use of GPS has become even more important. The technology now enables generation of digital elevation models and digital terrain models at very fine contour intervals.

E. Sri Lanka

32. The importation of GPS receivers was not regulated by the Telecommunications Regulatory Commission of Sri Lanka until 2000. This allowed the public and companies to import and use GPS receivers for various purposes. The applications of GPS in Sri Lanka may thus be used in several governmental and non-governmental institutions for different purposes. For example, each month more than 300 fully loaded super-tankers pass by the southern coast of Sri Lanka en route from the Middle East to the Far East. They use DGPS technology for safe navigation. There is an urgent need to upgrade existing navigation facilities. DGPS technology is also being used for hydrographic surveying and the fishing industry. Most deep-sea fishing vessels are equipped with GPS systems. Furthermore, the technology should also be used extensively in maritime research by the National Aquatic Resources Research and Development Agency, in the prevention of marine pollution by the Marine Pollution Prevention Authority and for prospecting in

oil and minerals by the Government of Sri Lanka, as there is tremendous potential.

F. Tonga

33. Aeroplanes and most of the maritime vessels operating in Tonga are equipped with GPS receivers. Most fishing boats are also equipped with GPS receivers, improving conditions for finding fishing areas. GPS is also used in the location and positioning of marine navigational aids in very remote areas. During the cyclone season the technology is used to locate cyclones and also to determine from satellite images the size of the cyclone.

G. Turkey

34. In the case of Turkey, three continent-sized plates are moving across the Earth's surface and interact along their edges. GPS technology, along with other technologies, was able to monitor crust deformation in and around the Sea of Marmara for seven years with high accuracy. The displacement of two rigid blocks along the North Anatolian fault was found to be about 2.5 centimetres per year.

35. There are a number of governmental bodies using GPS technology for marine and atmospheric data processing, land use and cadastral maps, forest fire monitoring and so on. Among them are the Istanbul Technical University, the Middle East Technical University, the Atomic Energy Council of Turkey, the Ministry of Environment and Forestry, a number of private digital geo-processing companies and others.

H. Uzbekistan

36. GPS receivers are used by organizations of the State Committee "UzGeoCadastr", the Surveying and Mapping Agency in Uzbekistan. They carry out geodesic-cadastral work in some parts of Uzbekistan's territory from 1996 using Navstar GPS receivers manufactured by the Ashtech (United States) and Leica (Switzerland) companies. The principal tasks are as follows: (a) creation, upgrading and maintenance of Uzbekistan's state geodesic network; (b) precise measurement of surveying and geodesic network coordinates; (c) planning work for construction of buildings; and (d) mapping using aerial and space images.

Notes

[1] *Report of the Third United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE III)*, chap. I, resolution 1, part I, para. 1 (e) (ii) and chap. II, para. 409 (d) (i).

United Nations A/AC.105/772

General Assembly

Distr.: General
7 December 2001

Original: English

Committee on the Peaceful Uses of Outer Space

Report on the Second United Nations/International Academy of Astronautics Workshop on Small Satellites at the Service of Developing Countries: the African Perspective

(Toulouse, France, 2 October 2001)

Contents

		Paragraphs	Page
I.	Introduction	1-6	2
	A. Background and objectives	1-4	2
	B. Attendance	5-6	2
II.	Summary of presentations	7-13	2
III.	Conclusions and recommendations	14-20	3

V.01-89575 (E) 100102 110102

I. Introduction

A. Background and objectives

1. The Third United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE III) recommended inter alia that the joint development, construction and operation of a variety of small satellites offering opportunities to develop indigenous space industry should be undertaken as a suitable project for enabling space research, technology demonstrations and related applications in communications and Earth observation.[1] Additional recommendations emanated from the activities of the Technical Forum held at UNISPACE III.[2] In accordance with those recommendations, the Office for Outer Space Affairs of the Secretariat has substantially extended its existing cooperation with the Subcommittee on Small Satellites for Developing Nations of the International Academy of Astronautics (IAA).[3]

2. At its forty-third session, in 2000, the Committee on the Peaceful Uses of Outer Space endorsed the programme of workshops, training courses, symposia and conferences planned for 2001.[4] Subsequently, the General Assembly, in its resolution 55/122 of 8 December 2000, endorsed the United Nations Programme on Space Applications for 2001.

3. At the 1999 meeting of the IAA Subcommittee, it was agreed that the fifty-first International Astronautical Congress, which was to be held in Rio de Janeiro from 2 to 6 October 2000, would be an ideal opportunity to review the status and advancement of programmes in Latin America. It was further agreed that the workshop should be open to participants from other regions, but that the situation in Latin America would be used as an example of how developing countries could benefit from small satellites and that it should form the core of the discussion. The report of the first United Nations/IAA Workshop (A/AC.105/745) was submitted to the Scientific and Technical Subcommittee at its forty-fourth session in 2001. Based on the positive response from participants and from States members of the Committee, it was decided that the second workshop, to be held in 2001, should encourage the development of small satellite technology in Africa.

4. The United Nations/International Academy of Astronautics Workshop on Small Satellites at the Service of Developing Countries: the African Perspective was held in Toulouse, France, on 2 October 2001. It was the second workshop organized jointly by the Office for Outer Space Affairs and Subcommittee on Small Satellites for Developing Nations of the International Academy of Astronautics within the framework of the International Astronautical Congress.

B. Attendance

5. The Workshop was an integral part of the International Astronautical Congress and was attended by as many as 40 registered Congress participants. Many of those attending the Workshop had also attended the United Nations/International Astronautical Federation Workshop on Making Space Applications Operational: Opportunities and Challenges for Sustainable Development, held in Albi, France, immediately before the Congress (from 27 to 29 September 2001) (A/AC.105/775). The sponsors of the workshop held in Albi (the United Nations, the European Space Agency and the Centre national d'études spatiales (CNES) of France) had provided financial support to selected participants from developing countries and the International Astronautical Federation had waived the registration fee for them.

6. One of the objectives of the Workshop was to review the advancements made in Africa in the development and utilization of small satellites in the light of the recommendations of the previous workshops organized by the IAA Subcommittee. The Workshop was also attended by several participants of previous workshops who provided valuable continuity and were able to assess progress made during the series of workshops.

II. Summary of presentations

7. Six papers were presented at the Workshop. Most of them described the current situation and advanced projects in Africa and in other regions.

8. The first paper, by the co-chairmen of the Workshop, gave an overview of the results achieved during workshops held at UNISPACE III and in Latin

America. Used as an introduction to the Workshop, the presentation stressed the applicability of the results and conclusions of previous workshops to the African countries.

9. The second paper, by the Director of the United Nations Office for Outer Space Affairs, underlined the importance of small satellites in the use of space technology for sustainable development. Emphasis was placed on capacity-building through technology transfer and training programmes. Financing and intellectual property rights associated with technology transfer were highlighted.

10. Based on the successful SUNSAT programme, South Africa was seeking further development of its space activities in relation to the actual needs of the African countries. The South African paper emphasized that real application needs existed, particularly if access to low-cost data could be provided for better decision-making. The SUNSAT programme had demonstrated that high-resolution remote sensing with small satellites was possible for applications such as agriculture, water resource management or disaster mitigation. The paper also indicated that existing technological capabilities, especially those developed in the framework of the SUNSAT programme, could be pulled together to execute a completely new programme. Finally, such a programme would provide economic benefits not only in the areas of application indicated above, but also in education and training, and in the development of industry and spin-off enterprises.

11. Participants were informed of a worldwide Disaster Monitoring Constellation Project consisting of five small satellites that would provide for daily revisit to a particular region to monitor rapidly changing conditions during disasters. Each satellite would be contributed by a different country. Algeria was building its first satellite, Alsat-1, as part of a know-how and technology transfer programme with the United Kingdom of Great Britain and Northern Ireland. Algeria and the United Kingdom were two of the five partners, together with another African country, Nigeria, and two Asian countries, China and Thailand. In addition to its primary mission as part of the constellation, each satellite could also be used for the particular needs of the respective member country. In the case of Algeria, monitoring of agricultural land use or industrial and marine pollution, or verification of cartography for infrastructure development were applications of great interest, as well as the more specific regional application for intensive desertification monitoring.

12. Tunisia expressed its interest in space activities, possibly in cooperation with other countries from the Maghreb region. A preliminary study had been undertaken as a cooperative exercise between Tunisia and France on a small satellite mission for climatic data collection and remote monitoring of lakes and dams. Other space applications in the field of telecommunications and for access to the information society were also mentioned as important goals for Tunisia.

13. A paper from Brazil presented another possible cooperative programme between continents, namely a global monitoring equatorial system derived from Brazil's remote sensing satellite Amazon Rainforest Observation System (SSR). The innovative programme, directed towards the specific needs of low-latitude regions and based on a small remote sensing satellite placed into an equatorial orbit, could increase the revisit frequency and provide near-real-time data transmission. Applications of such a satellite would be the monitoring of deforestation, forest fires, flooding, desertification, mineral exploitation or various sea activities. The receiving station and mission centre located in Africa could serve users in the African equatorial region, and preliminary contacts for such cooperation had been initiated.

III. Conclusions and recommendations

14. The Workshop clearly demonstrated that there were tremendous spin-offs to be gained from introducing space activities through a small satellite programme.

15. The Workshop stressed the importance of placing the main focus on those applications that would provide sustainable economic benefits for developing countries in Africa.

16. In the presentations, it was emphasized that, as the African experience grew, it could yield practical results by demonstrating that small satellites could be effective in addressing regional problems. For example, the reported experiences emphasized the importance of small satellite applications for remote

sensing, especially in the fields of disaster mitigation, agriculture, desertification and forest monitoring.

17. The participants in the Workshop recognized that small satellites were a useful tool for acquiring and developing technology and contributing to education and training.

18. The participants also recognized that small satellite projects in Africa were promoting international cooperation within the region, as well as with European and Asian partners.

19. The participants emphasized the need for greater awareness among the public and among decision makers.

20. The participants in the Workshop recognized that the proposals made during UNISPACE III were fully applicable to Africa, but they made the following additional conclusions and recommendations that were more focused on the specific needs of the region:

(a) The Workshop recognized that the route of international cooperation should be explored more in order to foster the use of small satellite systems for the benefit of African and other developing countries, especially through the promotion of regional projects. For that purpose, the Workshop recommended that coordinated action be initiated to identify significant problems that were common to different countries in the region and that could be addressed with the help of small satellite technology. The Workshop also recommended that partnerships be developed between regions with common needs, such as the equatorial regions of different continents;

(b) Efforts had been made to develop space systems devoted to improving the quality of life in developing countries. To provide maximum economic and social benefits to the population in such countries, the Workshop recommended that relevant programmes be established in such a manner as to ensure continuity and sustainability;

(c) The Workshop highlighted in particular the importance of Earth observation programmes for developing countries and the benefits of international cooperative efforts. The Workshop therefore recommended that long-term strategic programmes be developed to ensure the acquisition and processing of the data needed for monitoring the environment and natural resources, as well as for decision-making;

(d) The Workshop recognized the benefits of small satellite programmes in the acquisition of technology and the development of spin-off enterprises. The Workshop therefore recommended that space activities be an integral part of any national programme devoted to technology acquisition and development;

(e) Finally, the Workshop recognized the importance of space development in education curricula, especially for motivating and training students. In line with recommendations made at UNISPACE III, the Workshop proposed that each country recognize the important role that space assets could play in education and the need to incorporate space into education, as well as to develop among the population and among decision makers an awareness of the benefits offered by space technology applications.

Notes

[1] *Report of the Third United Nations Conference on the Exploration and Peaceful Uses of Outer Space, Vienna, 19-30 July 1999* (United Nations publication, Sales No. E.00.I.3), chap. I, resolution 1, annex, para. 32 (b).

[2] Ibid, annex III.

[3] The purpose of the IAA Subcommittee on Small Satellites for Developing Nations is to assess the benefits of small satellites for developing countries and to develop awareness on the subject in both developed and developing countries. The IAA Subcommittee publishes its findings and disseminates relevant information through workshops and symposia. In order to realize its goals, the IAA Subcommittee cooperates with: the United Nations and its Committee on the Peaceful Uses of Outer Space; the International Astronautical Federation and its Committee for Liaison with International Organizations and Developing Nations; and the International Space University.

[4] *Official Records of the General Assembly, Fifty-fifth Session, Supplement No. 20* (A/55/20), para. 37.